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NAVAL MEDICAL RESEARCH INSTITUTE

NATIONAL NAVAL MEDICAL CENTER

BETHESDA, MARYLAND

ENVIRONMENTAL AND PHYSIOLOGIC STUDIES ABOARD TWO AIR-COOLED HOSPITAL SHIPS EN ROUTE FROM NORFOLK, VIRGINIA TO THE CANAL ZONE

Research Project X-205 Report No. 4

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Part I. USS TRANQUILLITY(AH-14), 6-13 June 1945

SUMMARY AND CONCLUSIONS

1. The "effective" temperatures in the hospital and living spaces aboard this ship in the tropics were usually maintained within the limits for which the cooling system was designed, namely 76*, and never exceeded 78.5. This is equivalent to or cooler than weather air and represents a considerable improvement in living conditions over ships ventilated by the most efficient mechanical means where the "effective" temperatures in living spaces in the tropics are usually higher than 83 (dry bulb 7° to 10° above weather air), and men at rest sweat continually.

2. In a ward space occupied by hospital corpsmen for a period of one week during the cruise from the temperate to the tropical zone, the air conditions were conducive to proper rest and sleep without sweating. Basal oral temperatures averaged approximately 97, or 0.5 lower than temperatures recorded on personnel in a similar tropical area sleeping in the best mechanically ventilated space, and about one degree lower than oral temperatures of men sleeping under conditions existing in most of our warships cruising in the tropics. This slightly lower level of basal temperature was associated with a relatively dry skin free from eruption in contrast with the sweating skin and heat rash associated with the higher temperature level.

3. The mean basal oral temperature shows about the same degree of statistical stability, measured by the standard error, as does the rectal temperature. The mean oral temperature, taken with proper precautions, of a group of subjects appears to be as satisfactory as rectal in recording response of the body to changes in ambient air temperatures within a warm range.

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*All temperatures in this report are in degrees Fahrenheit.

4. The odor level was extremely low in the hospital corpsmen's and crew's berthing spaces, probably due to the absence of sweating, the relatively dry bedding and the removal of odoriferous material by the cooling coils. In mechanically ventilated ships, odors in such spaces reach objectionable levels.

5. The duration of periods of intensive exercise carried to exhaustion was increased from 84.6 seconds in the Norfolk area to 115 seconds in Panama.

6. Additional important findings were the maintenance of initiative, motivation, alertness, and the ability of the ship's crew to work for long periods and to recover from fatigue very rapidly. These observations were in striking contrast to the situation on the ships equipped with ventilation other than air cooling where irritability, lack of incentive, "morning stupor", and a continual struggle of personnel to overcome the fatigue debt by sleeping or lying around on all parts of the ship at all hours, are accepted as an inevitable result of the change from temperate to tropical waters.

7. On air-cooled hospital ships there are three major operational considerations; (a) maintenance of the air conditioning system in good working order, (b) the avoidance of a chilled atmosphere, and (c) the need to minimize odors arising from patients in the recirculated air.

INTRODUCTION

The air-cooled hospital ship has become a recognized necessity in tropical areas for the proper treatment of patients. Although statistics are not at hand to indicate the deaths or retarded recoveries of patients in ships not air-cooled operating in tropical areas, medical officers on such ships have stated that high temperature and humidity are major factors in prolonging disability and in increasing mortality of the sick and injured, particularly the burned. Even healthy men subjected continuously to high temperatures show a large loss of fluid and salt and an increased pulse rate indicative of cardiovascular stress. Even when at rest such men may lose 50 cc. of sweat per hour. It is obvious, therefore, that the difficulty of maintaining patients, especially surgical patients, in fluid and electrolyte balance in temperate climates is tremendously augmented in the tropics by an additional evaporative fluid loss of several liters.

At present the heat developed in living and working spaces aboard ship is dissipated by the addition of topside air by means of blower systems and the removal of heated air by mechanical and natural exhaust systems. Cooling occurs merely by dilution. Such a system can accomplish little in the way of producing a satisfactory temperature. The air in a compartment can be maintained at a point no less than 7 to 10° above the weather temperature. Medical officers in the Pacific combat zone have seen the effect of these conditions. Each morning they find a long sick call line made up largely of men complaining of heat rash, fungus infections, headache, and feeling below par.

In designing an air cooling system for a ship, the engineer is hampered by certain limitations. The amount of cooling equipment he can put aboard, due to weight and other military considerations, is restricted. The HAVEN class hospital ship, a cargo transport converted into a floating hospital with all hospital and living spaces air-cooled, is therefore of considerable interest. The cooling system aboard this class of ships is designed to maintain an "effective" temperature of 76 in tropical waters. "Effective" temperature is defined as an empirical index (1) which combines dry and wet bulb temperatures for any given air movement in a single value to denote the degree of warmth or cold felt by the human body. Any combination of wet and dry bulb temperatures giving sensation of warmth or cold identical with that produced by a given saturated still atmosphere is denoted by the same effective temperature value. Thus, 78 "effective" temperature is applicable to the following combinations of dry and wet bulb values in still air:

D.B.	W.B.	R.H.(%)
78	78	100
80	76	85
83	74	65
85	72.5	52
88	70	40
90	67	28

Certain engineering considerations regarding the cooling system are presented in the appendices and others are presented in greater detail in Part II of this report by Duffner and Ross. In the ward spaces about 15 cu. ft. per occupant per minute of fresh air are added and exhausted to control odors. The air in the compartment is recirculated across the cooling coils. In the living spaces about 7 cu. ft. per man per minute are exchanged.

The USS TRANQUILLITY is the third ship of this class. Certain difficulties regarding operation of the cooling installation had been reported and in order to aid the ship's force in the solution of these problems, a test party of engineers and a medical officer from this Institute were assigned by the Bureau of Ships and the Bureau of Medicine and Surgery to this ship. The ship left the Norfolk area on 6 June and arrived in the Canal Zone on 12 June. The role of the medical officer in the test party was to evaluate the physiological adequacy of the air cooling. This evaluation was made by observing the body temperatures and the pulse rate responses to exercise of a group of subjects. Critical evaluation of specific benefits in patients attributable to air cooling must necessarily await operational reports.

PROCEDURE

Air temperatures and humidities were recorded continuously in 17 compartments and three weather areas by means of hygrothermographs* which were checked periodically by means of sling psychrometers.

Oral and rectal temperatures were recorded at night on "turning in" and in the morning before arising on 26 of the 44 hospital corpsmen who acted as subjects and were berthed in a ward (C-6) for this study. Clinical thermometers were left in place for five minutes.

Both the cardiovascular and the endurance parts of the step-up test (2) as described in appendices 1 and 2 were administered to two separate groups of men on or about 7 June in the Norfolk area and again on 12 June in the Panama area. The first group of 40 men performed (a) the 30-second test (cardiovascular) and then (b) the endurance test. In (b) the step-up exercise was continued until the rate and rhythm could no longer be maintained, or for a total period of three minutes. The second group of 20 men engaged in four consecutive exercise periods similar to procedure (a) with rest intervals of 30 seconds followed by a final endurance test similar to procedure (b). In this group, pulse rate was recorded during the 5-20 second interval after each period of exercise. Morning and evening oral and rectal temperatures were recorded.

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*Portable temperature and humidity recorders manufactured by the Friez Instrument Division, Bendix Aviation Corporation.

Precautions were taken to ensure validity of data, i.e. the test was conducted in the morning before the work of the day; smoking and coffee drinking were interdicted for one hour prior to the test; the rate of exercise was governed by the beats of a metronome; stop watches were used in recording pulse rates; and both medical officers and subjects engaged in practice runs over a period of several days to eliminate the learning factor.

Procedure (a) was also employed over a period of eight hours in a hot space to record pulse rate response to a given work load. In this test, the periods of exercise were repeated once every 15 minutes and pulse rates were recorded with the subjects seated before exercise and at 5-20 and 105-135 seconds after exercise.

RESULTS

Air temperatures.- The weather air during the cruise varied from 53° and 92 per cent relative humidity to 90° and 55 per cent relative humidity (table 1).

Within the ship, "effective" temperatures between 76 and 78 were usually maintained in the air-cooled spaces (tables 1 and 2). Representative temperatures were 80-84 dry bulb and 70-73 wet bulb. The relative humidity was usually in the range of 60 to 80 per cent.

In a mechanically ventilated working space (sheet metal shop) the temperature range was 80-92 dry bulb and 75-80 wet bulb. The x-ray dark room was neither cooled nor adequately ventilated (D.B. 93, R.H. 43 per cent). These air conditions were similar to those in engine and fire rooms but were well tolerated by men engaged in light activity (repeated step-up tests) simulating the work required of watch standers (table 3).

Body temperatures.- A statistical analysis (table 4) shows that with stable environmental conditions (a) the distribution of both the oral and the rectal temperatures remains fairly stable, (b) the difference between them is significant, the average being about 0.5° but showing considerable variability among subjects, (c) the correlation between oral and rectal temperatures varies on different days from 0.49° to 0.87° in a manner apparently unrelated to environmental conditions, and (d) both respond similarly to ambient temperature changes (figure 1).

The average retest reliability between pairs of measurements made in each of the two periods is low;

Period	Date (June)	No. of men	Retest reliability coefficients (r) Oral	Rectal	Effective temp. Day weather	Night compart.
I	7, 8, 9	26	0.69	0.66	79.9	74.8
II	10,11,12,13	25	0.53	0.33	80.0	77.3

One may conclude from the data that oral temperatures in a group under controlled environmental conditions appear to be as precise and stable as rectal temperatures.

Pulse rate response and muscular endurance time.- The results of the 30-second "cardiovascular" step-up test did not change significantly on going from the temperate to the tropical zone. However, the average endurance step-up time increased from 84.6 to 115 seconds (P = 0.01) (table 5 A). Under uniform conditions this time remains fairly constant when retests are made as is shown by the following data obtained on submarine personnel (3):

No. of men	Average endurance time (seconds)
10	66.5 66.7*
16	66.8 66.9*
10	54.8 54.5**

*48 hours following first test.
**12 hours following first test.

The endurance time, however, was not significantly increased (78 to 83 seconds) in the group of men engaged in four 30-second periods of exercise prior to the final endurance test (table 5 B). It is likely that an extraneous factor such as sore legs from too much preliminary exercise (four 30-second periods instead of one) masked the true performance ability of this group of men.

General observations and subjective responses.- The chief benefits derived from the relatively cool living atmosphere under conditions of tropical operation were minimal odor in the berthing spaces, absence of sweating in the resting state, absence of heat rash, fewer skin infections, sustained motivation and initiative, and the ability to work that is characteristic of men in a cool environment. Outstanding was the fact that personnel could secure adequate rest and sleep in the berthing spaces in the period allotted for sleep. Men were alert on awakening in contrast to the transient stupor frequently observed in those men sleeping in mechanically ventilated spaces in the tropics. The contrast between the heat of Panama and the relatively cool air within the ship was especially stimulating. At the start of the cruise some difficulty was experienced in persuading the crew to keep ports and weather access doors closed, but in Panama no special effort was needed.

Although factors other than cooled air and adequate sleep may have contributed to improved work output (step-up exercise) it can be concluded that performance equal at least to that attainable in temperate climate can be maintained during the transition from temperate to tropical climate and during a period when acclimatization changes usually take place.

COMMENTS

Observations made during a similar cruise on a new carrier (4) are of interest by way of contrast. There was no cooling of the berthing space in the carrier. Men complained of heat and of broken sleep due to excessive heat. They felt tired and "dopey" upon awakening. The unanimous response from division officers was that the work output of the men was markedly less as the ship reached the tropics. The observers aboard the carrier reported that it was an easy climb in cool weather from the third deck to the signal bridge, a distance of about 80 feet. In the tropics, the climb seemed almost impossible and was accompanied by rapid pulse rate, dizziness and shortness of breath.

An "effective" temperature of 76, which the air cooling equipment aboard the USS TRANQUILLITY is designed to maintain, may appear high. The objectives of setting such a level were; (a) to provide cooling for efficiency rather than comfort, (b) to maintain the least difference between compartment and weather temperatures, compatible with efficiency, and (c) to provide conditions just below the sweating point of men at rest wearing minimal clothing. An atmosphere producing chilliness was avoided.

An average basal oral temperature of 97 (rectal 97.5) is observed under conditions in which sweating does not occur. If air temperatures are raised, however, so that the oral temperature is elevated 0.5-1.0°, sweating usually takes place. The relationships between oral, compartment and weather temperatures aboard a cooled and an uncooled ship cruising under essentially similar conditions are presented in figures 1 and 2.

Studies at this Institute (5) showed that in men who after 12 hours' daily exposure in a hot environment (90, D.B.; 83, W.B.; E.T., 85) subsequently spent 12 hours in a relatively cool atmosphere (80, D.B.; 70, W.B.; E.T., 75) the average morning basal rectal temperature was also 97.5. If the hot conditions also prevailed at night, the basal rectal temperature was elevated by about one degree in the morning.

In warm and hot atmospheres, the following averages for basal body temperatures are consistently obtained after a night's sleep;

Oral	Rectal	Air temp. "effective"	Condition of the skin
97	97.5	75 - 78	Dry
97.5-98	98.0-98.5	82 - 85	Sweating

The lag that appears in the response of body temperatures to changes in ambient temperature (figs. 1 and 2) may in part be explained by the fact that radiant heat (not computed in effective temperature) becomes effective physiologically after the ship as a whole becomes heated during the first few days in tropical waters. Additional factors responsible for variability in measurements were thought to be sunburn and acclimatization.

The mean basal oral temperature recorded on groups, provided that thermometers were left in place for five minutes and precautions were taken against local heating or cooling of the mouth, appears to be as satisfactory as rectal temperature in stability of recordings and responsiveness to changes in the temperature of ambient air (table 4). Average basal oral temperatures should therefore prove to be extremely useful in future studies aboard ship.

In the best ventilated, but not cooled, berthing space where approximately 40 cubic feet of outside air are supplied per man, air temperatures are seven to ten degrees above weather air temperature and the humidity is increased due to moisture uptake within the ship to give a difference of about five units in "effective" temperature (fig. 2). In the air-cooled ship, the weather temperatures (average 78 E.T.) are seldom exceeded by the compartment temperature and it is possible to reduce the outside air supply from 40 to 7 or less cubic feet per minute per man in the interest of economy without deleterious effects or discomfort.

Air cooling in which considerable quantities of moisture are condensed out of the air appears to be effective in removing odors. Whether it is adequate to take care of the odors associated with certain types of patients is not known. It is possible that individual charcoal units (6) will be required for such patients.

There is a tendency, especially notable before personnel become acclimatized to tropical heat, for those operating the cooling system to attempt to maintain a "chilled" atmosphere. This results in too great a difference between weather and compartment temperatures and is thought to predispose to infection of the respiratory tract.

Since the medical aspects of ventilation require specific knowledge, it is suggested that aboard each hospital ship a medical officer be designated as liaison between medical personnel and ship's operating force. This officer should know not only the physiologic principles underlying heat transfer from the body but also understand the precise mechanics involved in supplying refrigerated air to spaces.

Although a complete breakdown of the air-cooling machinery is unlikely because of the large margin of safety provided, nevertheless such an event would cause the reduction of available ventilation in the berthing spaces to some 7 cubic feet of air per man per minute or about 20 per cent of the air usually supplied by mechanical ventilation. Constant vigilance is therefore necessary to ensure the proper operation of equipment. The medical liaison officer should request from the engineer only minimal air cooling, equivalent in general to "effective" temperatures of 76 to 78 which have been found to permit body heat loss without visible sweating by healthy, acclimatized personnel at rest.

Appendix 7 summarizes instructions formulated by engineers with wide experience in naval ventilation problems.

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A. R. BEHNKE
Captain, (MC), USN

Table 1 (Part I).- Range of weather and compartment (Ward C-6) air temperature and humidity en route from Norfolk to Panama

Date June 1945	Range of sea water temp.	Range of weather air				Range of compartment air			
		D.B.	W.B.	R.H.	E.T.	D.B.	W.B.	R.H.	E.T.
3	--	62-80	58-66	80-50	61-74	--	--	--	--
4	--	54-64	51-57	85-65	53.5-62	--	--	--	--
5	--	53-62	52-52	92-50	53-59.5	--	--	--	--
6*	--	60-80	54-65	70-45	58.5-73.5	72-68	55-60	62-60	68-66
7	71-80	68-84	63-73	75-60	66.5-78	72-68	55-90	62-67	68
8	77-81	74-88	72-77	90-60	73-82	68-82	85-70	65-74	67-78
9	80-83	80-82	77	90-85	78.7-79.7	82	75	76	78.5
10	81-83	78-80	77	95-90	78-78.7	76-82	80-70	72-74	74-78
11	82-84	76-90	74-77	90-55	75-82	78-80	80-70	73-72	76-76
12**	84	80-83	78-80	95-85	79.5-81	78-80	80-70	73-72	76-76
13	84	76-80	78-77	88-88	75-78.3	78-80	75-80	73-75	75-77

*Underway from Norfolk.

**In Canal Zone.

Table 2 (Part I).- Temperature in certain spaces during a cruise from Norfolk to Panama, 6-13 June 1945

Space	Temperature	Relative humidity
1. Operating room #1	82	64
2. Operating room #2	82	64
3. Fracture operating room	82	64
4. Central surgical supply	80	70
5. EENT clinic	82	73
6. X-ray dark room	98	43
7. Ward C-6	82	75
8. S.O.Q. quarters	82	55
9. Chaplain's office	80	70
10. Officer's mess	82	60
11. C.P.O. berth	82	65
12. Crew berth	82	65
13. Crew berth	82	65
14. Crew berth	82	65
15. Crew mess	82	70
16. Crew lobby	84	60
17.* Sheet metal shop	88	78

*Mechanically ventilated with weather air.

Table 3 (Part I).- Data on two men in x-ray dark room (frame 184, 1st platform) performing 20 step-ups every 15 minutes under simulated maximal condition of operation

Time	Subject A					Compartment temp. DB RH	Subject B				
	Oral temp. °F.	Pulse seated	Pulse 5"-20"	Pulse 105"-135"	Fluids		Oral temp. °F.	Pulse seated	Pulse 5"-20"	Pulse 105"-135"	Fluids
1030	98	84	116	96			98	84	116	84	
1045		84	124	84		94 60		84	108	84	
1100		84	116	92	1 glass			80	120	82	
1115		96	116	96				80	112	80	
1130	98.6	84	112	92	2 gls.		98	80	108	76	1 glass
1145		92	116	96				84	104	80	2 gls.
1200	98.6	80	116	88			98	84	108	80	
1215						94 45					
1230	98.6	80	116	92			98.2	84	120	88	
1245		80	120	92				80	112	84	
1300		92	108	104				88	116	84	
1315		92	116	104				84	112	88	
1330	98.6	94	116	92			98	92	124	84	
1345		100	124	96				96	120	88	
1400	98.8	96	120	96			98.4	100	128	104	1 glass
1415		92	120	96				84	120	84	
1430		92	128	96	2 gls.			88	116	88	
1445		88	124	92				88	112	92	
1500	98.8	92	120	96			98	84	116	84	
1515		96	116	96	1 glass			84	124	100	1 glass
1530		100	120	100				96	120	100	
1545		84	116	92				80	108	94	
1600	98.6	96	116	100			98	84	104	88	
1615		92	116	100				80	108	88	
1630		92	112	96				88	112	92	
1645		96	120	96				92	120	88	
1700	98.6	96	116	96	1 glass		98.2	88	120	96	1 glass
1715		92	120	96				96	108	92	
1730		84	120	84				88	112	88	
1745		84	116	84	1 glass			88	112	88	1 glass
1800	98.6	96	120	96		95 45	97.8	84	108	88	

Table 4 (Part I).- Comparison of oral and rectal basal temperatures recorded on 26 men sleeping in an air-cooled ward en route from Norfolk to Panama

Date June	7	8	9	10	11	12	13
Effective temperature:							
Day weather	78	82	79.7	78.7	82	81	78.3
Night compartment	68	78	78.5	78	76	76	77
Number of subjects	26	26	26	25	25	25	25
Oral temperatures:							
Mean	96.87	96.67	96.65	97.25	97.07	97.21	96.90
S.D.	.47	.35	.38	.40	.54	.57	.52
Rectal temperatures:							
Mean	97.29	97.26	97.05	97.70	97.58	97.47	97.62
S.D.	.48	.41	.52	.34	.70	.61	.46
Difference (rectal-oral):							
Mean	.42	.59	.40	.45	.51	.26	.72
S.D.	.29	.21	.28	.30	.40	.50	.46
Probability difference obtained is due to chance	.001	.001	.001	.001	.001	.01-.02	.001
Correlation between oral and rectal temperatures	0.56	0.75	0.76	0.68	0.87	0.68	0.49

Table 5 (Part I).- A. Average pulse rates and endurance time of 40 men performing a step-up test (1) in the Norfolk area and at Panama

Date	Standing P. R.		P.R. 5"-20" post exercise		P.R.105"-135" post exercise		Endurance time(2) seconds		P.R.5"-20" following endurance test	
	June 7	June 12	June 7	June 12	June 7	June 12	June 7	June 12	June 7	June 12
Range	64-116	64-116	23-39	23-39	32-58	29-57	43-145	48-180(4)	30-56	32-54
Mean	92	88	33	32	44.6	42	84.6	115	43	44
Median	92	88	33	31	43	41	80	122	43	44
Interquartile Range (3)	80-104	80-96	30-36	28-35	41-49	35-49	65-105	78-172	38-46	42-46

B. Pulse rates on 20 men 5"-20" after each of 4 step-up(5) periods followed by an endurance test and a 5"-20" pulse rate record

Date	Standing P.R.	5"-20" post exercise	5"-20" post exercise	5"-20" post exercise	Endurance time	5"-20" post endurance
June 7, 8	--	30	36 38	40	78	42.5
June 12	90	32	36 38	39	83	42.8

(1) 20 Step-ups made to a height of 18 inches during a 30-second period.
(2) Step-up exercise continued to limit of endurance.
(3) Tenth and thirtieth pulse rate values (25% above and below median), when these values are arranged in order of increasing magnitude.
(4) Endurance test terminated on 6 men at the end of 180 seconds.
(5) 30 seconds of exercise (20 step-ups) followed by 30 seconds rest.

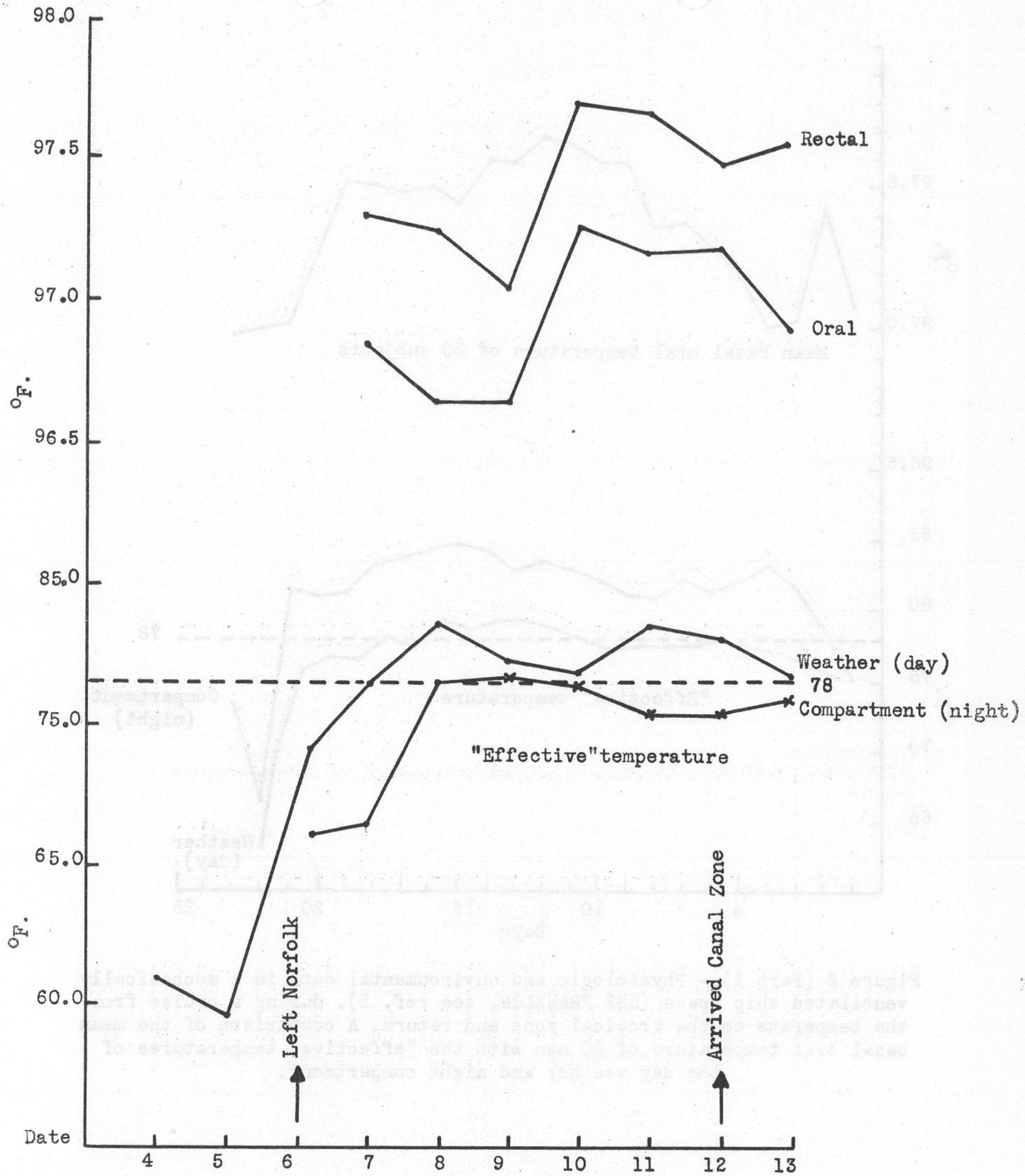

Figure 1 (Part I).- Physiologic and environmental data in an air-cooled hospital ship space (USS TRANQUILLITY), during a cruise from the temperate to the tropical zone. A comparison of the mean basal rectal and oral temperatures of 26 men with the "effective" temperatures of the day weather and night compartment.

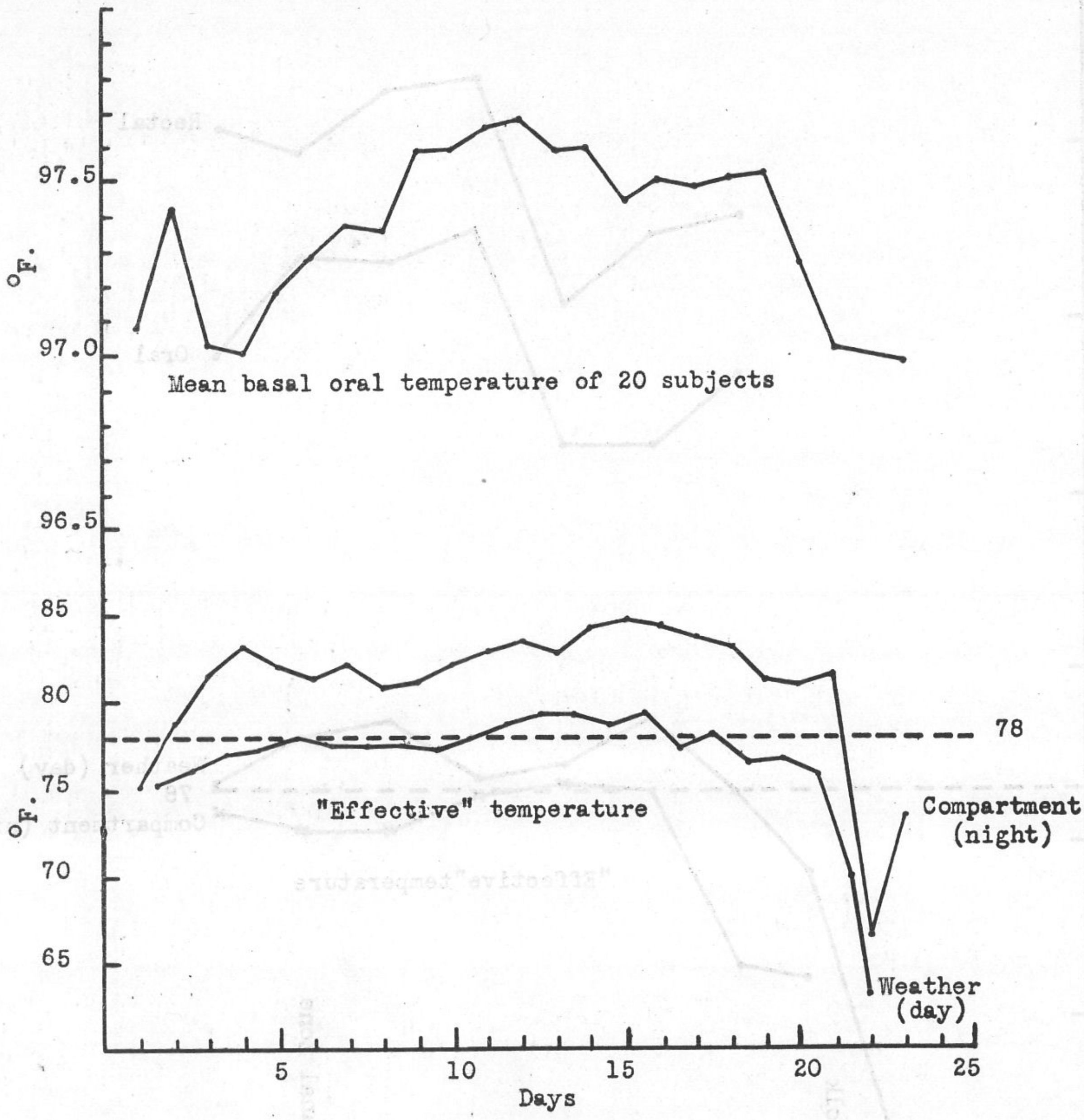

Figure 2 (Part I).- Physiologic and environmental data in a mechanically ventilated ship space (USS FRANKLIN, see ref. 5), during a cruise from the temperate to the tropical zone and return. A comparison of the mean basal oral temperature of 20 men with the "effective" temperatures of the day weather and night compartment.

Part II. USS CONSOLATION (AH-15), 14-20 July 1945

SUMMARY AND CONCLUSIONS

1. Air temperatures and relative humidity determinations (sling psychrometer) were made throughout the ship. The values obtained indicated that the system was operating in accord with its design, namely to provide an "effective" temperature of 76 or less in the cooled spaces.

2. Dust counts were made in the operating room suite using a Zeiss konimeter. Such small amounts of dust were found that further control seems unnecessary.

3. Two experiments were performed with volunteers from the ship to determine the effect of the prevailing air conditions on men traveling from a temperate to a tropical climate. Two "step-up" tests were used to determine changes in physical condition. In the first experiment no difference in performance was observed between men sleeping in cooled spaces and those sleeping in uncooled spaces. The results of the second experiment indicate that the subjects sleeping in an air cooled ward improved in physical condition during transit from a temperate to a tropical climate.

4. Morning and evening oral temperatures were measured on 22 subjects who slept in an air-cooled ward. The mean morning temperature was 97.24 and the mean evening temperature was 97.89.

5. A continuous temperature and relative humidity record of this ward is presented. Diagrams illustrating which parts of the ship are air-cooled and some of the engineering details are appended.

BACKGROUND

Part I of this report summarized environmental and physiologic observations aboard the USS TRANQUILLITY, the third of the "HAVEN" class hospital ships in which all hospital and living spaces are air-cooled. This part of the report summarizes observations made by a test party aboard the USS CONSOLATION, the fourth of this class of ships.

The air cooling system on these ships is a direct expansion freon 12* system. The heat exchange is accomplished by 53 cooling coils, which receive freon from eight compressors. The compressors and condensors are divided into four pairs and are placed on the ship in four widely spaced locations. The freon 12 is piped from each of the compressor-condensor units to a number of cooling coils. The compressors are so arranged that, should one of them fail, the other can be connected to both systems. The cooling coils are inserted into the 25 recirculating systems distributed about the ship. The air in the compartment is moved across these cooling coils at a designed face velocity of 550 feet per minute. The small quantity of fresh air entering the compartments, known as replenishment air, is placed in the recirculating systems in one of two ways. It is either drawn directly into the system by the recirculating blowers (appendix 3) or is added to the return air duct by a separate supply system (appendix 4). The air to be exhausted is usually drawn from heads, passageways or diet pantries. These spaces are supplied by air which enters from adjoining spaces by way of louvers in the doors or bulkheads. The cooling coils are provided with lucite cleanout plates so that the coil can be readily inspected.

The temperature of the ambient air in the spaces is controlled by thermostats in the recirculating duct. When the temperature of the air flowing past the thermostat rises above the temperature at which the instrument is set, an electric circuit is closed causing the magnetic field in a solenoid valve to be energized. This allows freon to flow through the expansion valve to the coil.

In the operating room suite a special installation has been made to reduce the noise. Large mufflers have been installed on the exhaust intakes in the operating rooms and the blowers have been secured on rubber mountings; this greatly reduces the vibration and noise.

PROCEDURES

Observations were directed along two lines: the first to study the air conditions as regards temperature, humidity and dust content, and second to determine the effect of these conditions on personnel. Wet and dry bulb temperature determinations were made with a sling psychrometer at points about the ship to evaluate the operation of each of the 53 cooling coils. These readings were made twice during the day and twice at night. Dust

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*Dichloro-diflouro methane.

counts were made with a Zeiss konimeter in the operating room suite, clinical laboratory and isolation wards after the ship had been at sea two days.

Two experiments were performed to determine the effect of living in a cool shipboard atmosphere upon personnel in transit from a temperate to a tropical climate. In the first experiment, two groups of volunteers were used. The first group consisted of men billeted in the sheet metal and carpenter shops. These spaces were not air-cooled. The second group worked and slept in cooled spaces. Each group did the step-up test (2) in the temperate climate (Norfolk, Va.) and again in the tropics (Canal Zone) seven days later. A detailed description of the step-up test is presented in appendix 1.

In the second experiment 22 subjects who slept in an air-cooled ward were used. A constant recording of the temperate and relative humidity of this space was made using a hygrothermograph*. The basal morning and the evening oral temperatures of this group were taken each day. The morning temperature was measured immediately before rising, the evening at 1630 when the day's work was done. The subjects left the thermometers in their mouths for at least three minutes before reading. At 0830 each morning the subjects performed the repeated step-up exercise test. In this test the subject steps up and down on a bench 18 inches high 20 times in 30 seconds, then rests for 30 seconds and alternates exercise periods and rest periods until a total of four exercise periods have been completed. The pulse is counted for each 5-20 second period following the exercise. Thirty seconds after completing the fourth exercise period the subject attempts an "endurance run" in which he steps up and down on the bench until he can no longer maintain the rhythm. The data sheet used for this experiment is presented in appendix 2.

RESULTS

The results of the temperature studies (table 1) indicate that most of the systems are operating at their designed temperatures.

The dust counts (table 2) in the surgical suite are relatively low and indicate that further dust control measures are not needed in these spaces.

The results of the step-up tests (table 3) show no significant difference between the performance of the men who slept in a cool place and those who slept in an uncooled place. The subjects who were billeted in the uncooled carpenter and sheet metal shops, however, also spent a certain part of the day in cooled spaces such as the messing compartment.

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*Portable temperature and humidity recorders manufactured by the Friez Instrument Division, Bendix Aviation Corporation.

The results of the repeated step-up exercise experiment are presented in figure 1. These tests were done only while the vessel was at sea and the subjects were given four days training prior to getting underway. A marked improvement in physical condition is shown during transit from a temperate to a tropical climate in a period of six days. The mean endurance time increased steadily from day to day, from 104.79 seconds in the temperate zone to 141.93 in the tropics. It will be noted that the pulse rates following each exercise period were remarkably constant. This experiment was started with 22 subjects, but six were dropped during the test period because of seasickness and muscle "soreness" in the legs, and two because they could not complete four exercise periods.

The mean morning temperature was found to be 97.24, and the mean evening temperature 97.89 (fig. 2). It will be noted that these temperatures are approximately one degree lower than those usually encountered aboard ship in tropical waters.

The hygrothermograph tracing showing temperature and relative humidity values (fig. 3) indicates that the latter fluctuates widely. The amount of moisture in the compartment air decreases at night, rises at reveille and reaches a peak during the exercise period.

COMMENT

No significant difference was found between the performance of the step-up test in those men who slept in a cooled space and those who slept in an uncooled space. The performance of this test, however, is affected a great deal by the subject's motivation. This allows a man to make a score which does not accurately reflect his state of well being. When the ship reached tropical waters the crew as a whole appeared much more alert than similar groups previously observed on a ship transiting from a temperate to a tropical climate. It is believed, therefore, that the crew was greatly benefited by spending a part of the day in a cool place.

The temperatures presented in the table are by no means a final picture of the operating conditions of the entire cooling system. It is a new installation and many minor mechanical adjustments are necessary before the system will perform at peak efficiency.

There were a number of bare flanges and valves in steam lines about the ship. These hot metal surfaces act as radiators and place an additional heat load on the cooling system. This condition accounts, in part, for the high air temperature encountered in the Senior Medical Officer's office.

The cooled atmosphere on the "HAVEN" class hospital ships should be a valuable aid in treating patients. The maintenance of the fluid balance of patients suffering from shock and burns will be made easier because the amount of water and salt lost in perspiring will be greatly reduced.

It has been pointed out in Part I of this report that these ships were designed to have an "effective temperature" of 76. While this may not be the ideal temperature for summer comfort, it will prevent sweating and alleviate discomfort in the tropics. A cooling plant to maintain "effective temperatures" much lower than 76 cannot be installed on ships due to the limitation on the weight which can be put aboard for this purpose.

ACKNOWLEDGMENT

The authors wish to express their appreciation for the cooperation given them by the following officers of the USS CONSOLATION: Captain P. G. Beck, USNR, Commanding Officer; Captain L. R. Newhouser, (MC), USN, Senior Medical Officer; Lieutenant (jg) W. A. Brown, USNR, "A", Division Officer; Lieutenant (jg) R. P. Noble, MC, USNR; and Lieutenant (jg) E. Henneman, MC, USNR.

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Table 1 (Part II).- Mean compartment temperatures, USS CONSOLATION, 18, 19 and 20 July 1945

Weather air temp.: 82 Weather rel. hum.: 90%						
Compartment	Deck	Frame and side	System	Wet bulb	Dry bulb	"Effective" temp.
Radio room	Br. dk.		03-60-3	71	77	74.3
Main comm. office	Br. dk.		03-60-3	67	73	70.5
Nurse S.R.(inboard)	Boat deck		03-60-3	75	80	77.5
Nurse S.R.(outboard)	Boat deck		03-60-3	75	81	78
SOQ (inboard)	Boat dk.		02-106	69	77	74.8
SOQ (outboard)	Boat dk.		02-106	71	78	75
SO mess & lounge	Boat dk.	90 CL	02-106	69	76	73
Surg. dr. room	Boat dk.	110 CL	02-106	70	78	74.5
Sick ward	Boat dk.		02-142	71	78	75
Surg. dr. rm.	Boat dk.	129 CL	02-142	72	79	76
Sick ward	Boat dk.		02-142	70	76	73.5
Nurses mess	Up. dk.		03-60-1	74	78	76
Officers mess	Up. dk.		03-60-1	75	80	77.5
Ortho. ward	Up. dk.	84-108 P	02-104	67	72	70.5
EENT ward	Up. dk.	84-104 S	02-104	70	75	73
GU ward	Up. dk.	110-125 P	01-125-1	72	77	75
Derm. & syph. wd.	Up. dk.	110-125 P	01-125-2	72	76	74.5
Isolation ward	Up. dk.	126-144 P	01-133-land 2	69	74	72
Isolation ward	Up. dk.	126-144 S	01-134-land 2	68	74	72
Surg. dr. room	Up. dk.	135 CL	01-134-1	70	76	73
First lieut.Off.	Up. dk.	148-156	02-147	75	82	78.5
Sheet metal shop	Main dk.	18-32 P		79	84	86*
WRSR passage	Main dk.	50 P&S	01-54	73	80	76.5
Off. & nurses gall.	Main dk.	45-54 CL	01-54	80	88	83.5*
NP ward	Main dk.	61-79 P	1-70	71	80	76
NP ward	Main dk.	61-79 S	1-70	74	83	78.5
Surg. dr. room	Main dk.	82-87 CL	1-90	72	79	76
Surg. ward	Main dk.	84-109 P	1-90	71	77	74.5
Surg. ward	Main dk.	84-109 S	1-90	71	78	75
Medical ward	Main dk.	116-139 P	1-133	70	78	74.5
Medical ward	Main dk.	116-139 S	1-133	71	82	77
Lobby	Main dk.	139-150 CL	02-147	74	82	78
Ambulatory ward	Main dk.	146-164 P	02-147	70	77	74
CPO mess	Main dk.	151-159 S	02-147	75	84	78
CPO berthing	Main dk.	159-169 S	02-147	76	84	80
Library	Main dk.	168 P	02-147	72	81	76.5
Ship's office	Main dk.	177 P	01-176	75	84	78.5
Supply office	Main dk.	186 CL	01-176	75	85	79.5
Corpsmen's berth.	Main dk.	174-188 S	01-176	78	84	76
Receiving room	Main dk.	190 S	01-197	78	87	83*

Table 1 (Part II) (Continued)

Weather air temp.: 82 Weather rel. hum.: 90%						
Compartment	Deck	Frame and side	System	Wet bulb	Dry bulb	"Effective" temp.
Laundry	Main dk.	[illegible]	01-197	78	86	82.5*
WRSR passage	2nd dk.	50 P & S	01-54	69	78	74
Ambulatory ward	2nd dk.	61-79 P	2-81	76	83	79.5
Ambulatory ward	2nd dk.	61-79 S	2-81	75	83	79
Operating room #1	2nd dk.		2-88-1	70	78	74.5
Anesth. room	2nd dk.	82-87 P	2-88-4	70	77	74
Operating room #2	2nd dk.		2-88-2	69	76	73
Operating room #3	2nd dk.	90-97	2-89	67	75	73
Clinic lab.	2nd dk.	97-110 P	2-107	71	81	76
SMO office	2nd dk.	82-88 S	2-107	75	85	79.5
MedRecOf	2nd dk.	88-99 S	2-107	75	84	79
MedLibrary	2nd dk.	109-114 S	2-107	75	84	79
CentralSurgSup	2nd dk.	100-105 CL	2-107	73	83	78
Crew's mess	2nd dk.	114-141 P&S	2-124	77	84	80
Corpsmen's berth.	2nd dk.	146-164 P&S	02-147	73	81	77
Crew berthing	2nd dk.	172-194 P&S	01-176	76	83	79
WRSR passage	1st plat.	32-56 P&S	01-54	70	79	75
Main issue room	1st plat.	61-72 CL	1-80-1	78	85	81*
Physiotherapy	1st plat.	86-93 S	2-107	72	83	77.5
Dental clinic	1st plat.	85-95 P	2-107	72	80	76
X-ray exam.	1st plat.	98 P	2-107	73	82	77.5
Radiog. room	1st plat.	105 P	2-107	73	82	77.5
EENT clinic	1st plat.	99 S	2-107	73	81	77
EENT-OR	1st plat.		3-110	74	81	77.5
Endoscopic room	1st plat.	110 P	3-110	73	83	78
Crew berthing	1st plat.	172-194 P&S	01-176	79	86	82**
Autopsy room	hold	82-90 CL	2-107	80	84	82

*Mechanical cooling only.

**Cleanout plate had been removed from cooling coil in space above, depriving this space of cooled air.

Table 2 (Part II).- Dust counts in surgical suite and isolation wards, USS CONSOLATION, at sea (A Zeiss konimeter was used)

Space	Particles - cu. ft.
Clinical laboratory	9,440
Operating room lobby	10,768
Central surgical supply	132,000
Anesthesia room	209,500
Fracture operating room	5,600
Operating room #1	trace
Operating room #2	trace
Isolation ward lobby	105,000
Isolation ward utility room (S)	89,000
Isolation ward utility room (P)	94,500
Isolation ward 5 A	110,000
Isolation ward 5 B	112,000
Isolation ward 6 A	95,000
Isolation ward 6 B	312,000

Table 3 (Part II).- Results of step-up tests performed on two groups of men at Norfolk, Va. and the Canal Zone. Group 1 consisted of 14 men billeted in uncooled spaces; Group 2 consisted of 17 men billeted in cooled spaces.

	Group 1	Group 2
Mean standing pulse (beats/min.)		
Norfolk	95.42	87.76
Canal Zone	93.78	91.05
Mean change in standing pulse	- 1.65	+ 3.29
Per cent of subjects showing increased standing pulse in Canal Zone as compared to Norfolk	35.7	52.9
Mean pulse 5"-20" after exercise		
Norfolk	33.5	31.41
Canal Zone	31.8	31.41
Mean change in pulse 5"-20" after exercise	- 1.7	0.00
Per cent of subjects showing increased pulse 5"-20" after exercise in Canal Zone	21.4	47.0
Mean pulse 105"-135" after exercise		
Norfolk	46.93	45.06
Canal Zone	44.93	44.88
Mean change in pulse 105"-135" after exercise	+ 2.00	- 0.18
Per cent of subjects showing increased pulse 105"-135" after exercise in Canal Zone	42.9	52.9
Mean C.V.S. score		
Norfolk	80.43	77.06
Canal Zone	76.78	76.29
Mean change in C.V.S. score	- 3.65	- 0.77
Per cent of subjects showing increased C.V.S. score in Canal Zone	28.6	52.9
Mean endurance time		
Norfolk	69.50	93.41
Canal Zone	84.14	92.94
Mean change in endurance time	+14.64	- 0.47
Per cent of subjects showing increased endurance time in Canal Zone	92.9	64.7
Mean pulse 5"-20" after endurance run		
Norfolk	38.50	36.53
Canal Zone	39.86	39.06
Mean change in pulse 5"-20" after endurance run	+ 1.36	+ 2.53
Per cent of subjects showing increased pulse 5"-20" after endurance run in Canal Zone	42.9	58.8

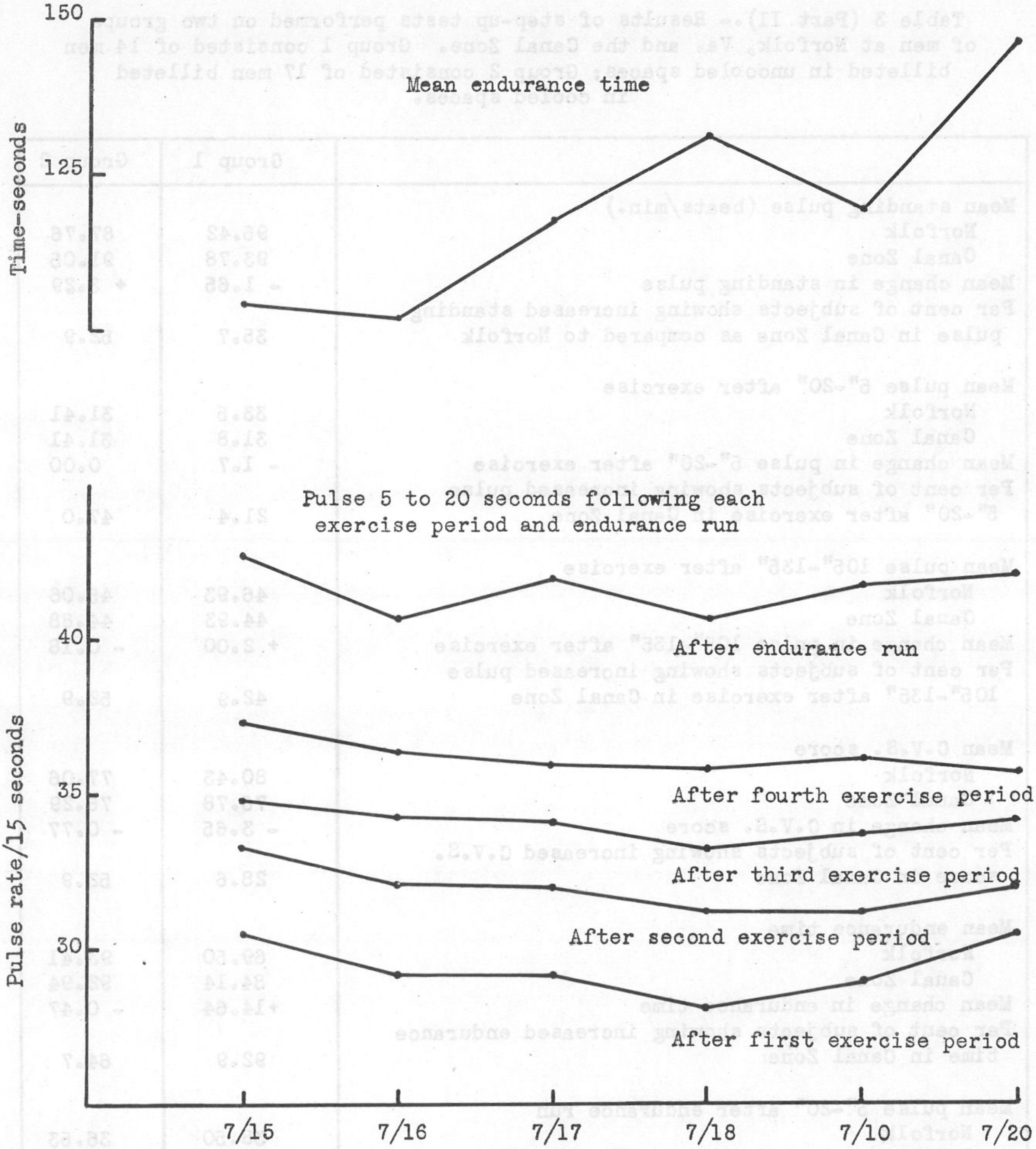


Figure 1 (Part II).- Results of "repeated step-up exercise tests" performed daily on 14 men sleeping in an air-cooled ward

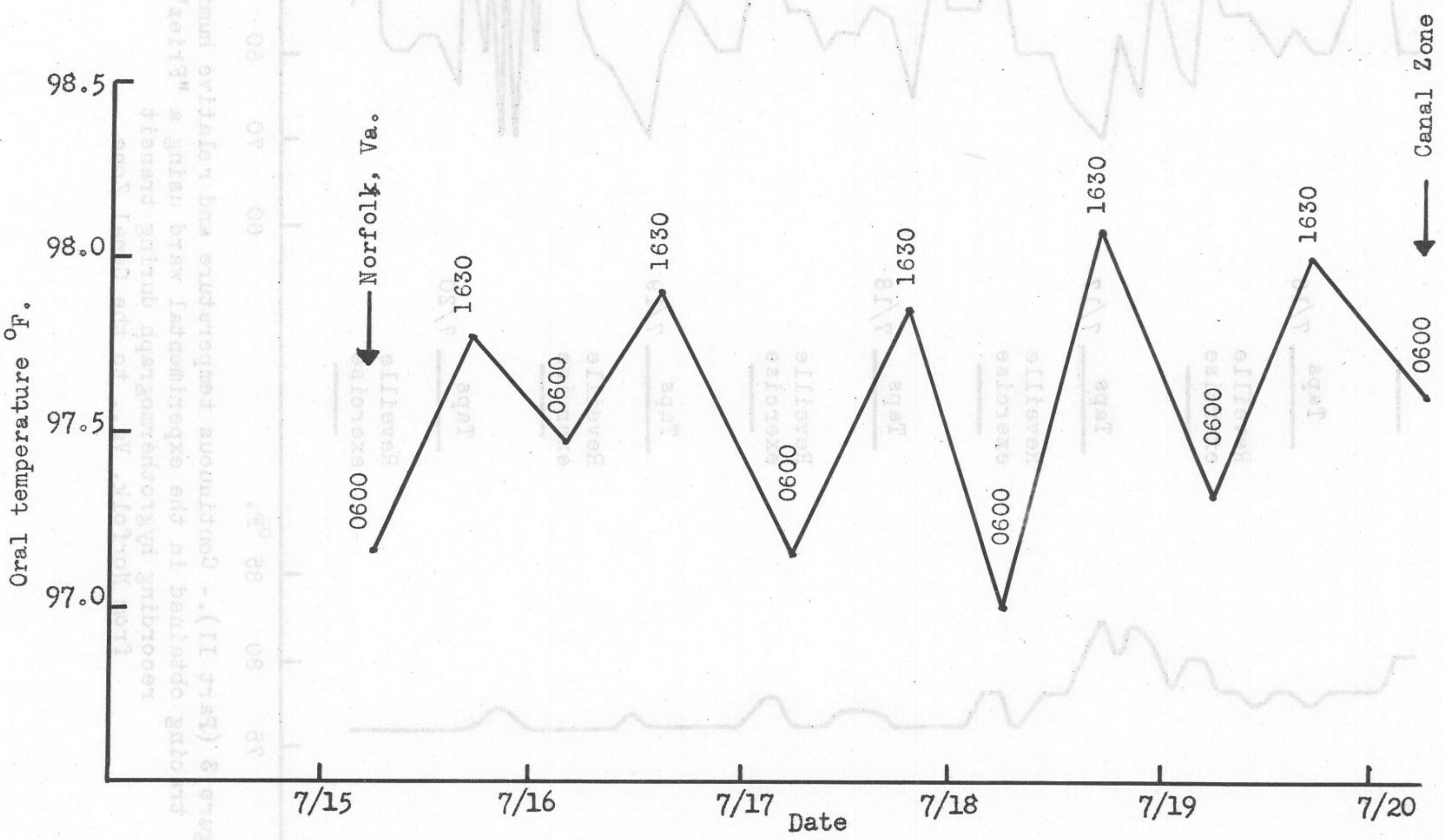


Figure 2 (Part II).- Mean morning and evening oral temperatures
22 men sleeping in an air-cooled ward

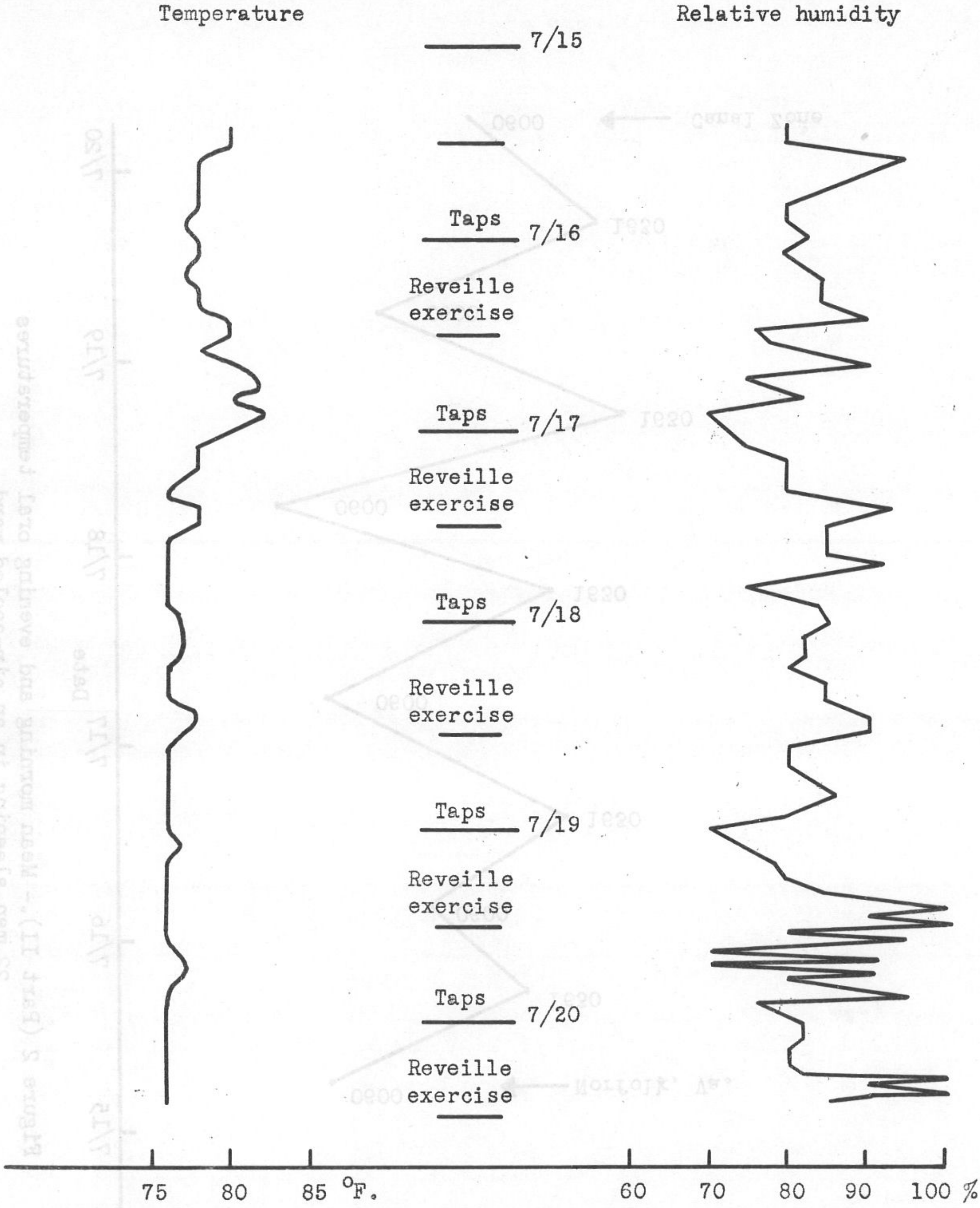


Figure 3 (Part II).- Continuous temperature and relative humidity tracing obtained in the experimental ward using a "Friez" recording hygrothermograph during transit from Norfolk, Va., to the Canal Zone

Appendix 1

INSTRUCTIONS FOR STEP-UP TEST

1. PURPOSE: The object of the step-up test is to employ a simple procedure executed precisely and under controlled conditions for the dual purpose of recording heart response following moderate exercise and of measuring muscular endurance.

2. MATERIALS NEEDED: A. Stop watch; B. Box or bench 18" high; and C. Metronome, pendulum or other timing device.

3. PROCEDURE: The test is conducted in the morning before the day's work begins. Smoking and coffee drinking are not permitted during the hour preceding the test.

4. DETAILS OF CONDUCTING THE TEST:

A. The subject places one foot firmly on the bench. Either foot may be used but the same leg must be used for lifting during the entire test.
B. Count the subject's pulse beats for 15 seconds while he is standing in this position and record in column (2).
C. The subject now steps up and down on the bench 20 times in 30 seconds. This exercise is done in rhythm using a timing device. The subject must step precisely with the signal and straighten the knee of the lifting leg as the other foot is placed on the bench.
D. After stepping down the 20th time, the subject turns and sits down on the bench.
E. The observer at this time resets his stop watch to zero, immediately starts it again and locates the subject's radial pulse.
F. When five seconds have elapsed he begins to count the subject's pulse. He counts the number of beats in the 15-second period between 5" and 20" after the subject sits down and records this value in column (3).
G. The observer lets the stop watch run on.
H. When 1'45" have elapsed the observer again begins to count the number of pulse beats in the 30-second period between 1'45" and 2'15" and records this value in column (4). The stop watch is allowed to run on.
I. When 2'30" have elapsed, the subject stands and assumes the position described in A.
J. The stop watch is reset to zero.
K. The endurance run is now started. The subject exercises as in C except that the stepping up and down is continued until he can no longer keep up the rhythm. He then sits down on the bench.
L. If the subject continues this exercise for 3 minutes, the observer stops him at the end of that time.
M. The endurance time in seconds is recorded in column (6).
N. The stop watch is reset at zero and started immediately.
O. When the subject has been seated for 5 seconds, his pulse is counted in the period from 5" to 20" and recorded in column (7).

(DATA SHEET ON OTHER SIDE)

DATA SHEET FOR STEP-UP TEST

(See other side for instructions)

(NAME)	(RATE)	(AGE)
(SHIP OR STATION)	(HEIGHT)	(WEIGHT)

Date and time (1)	Standing pulse (2)	CARDIOVASCULAR: Pulse 5"-20" after exercise (3)	CARDIOVASCULAR: Pulse 1'45"-2'15" after exercise (4)	CARDIOVASCULAR: C.V.S. score col.3+ col.4 (5)	ENDURANCE: Endurance time (6)	ENDURANCE: Pulse 5"-20" after exercise (7)	Compartment temperature: Dry bulb	Compartment temperature: Wet bulb

REMARKS:

Appendix 2

DATA SHEET FOR "REPEATED STEP-UP TEST"

SHIP or STATION ______________________

REPEATED STEP-UP EXERCISE

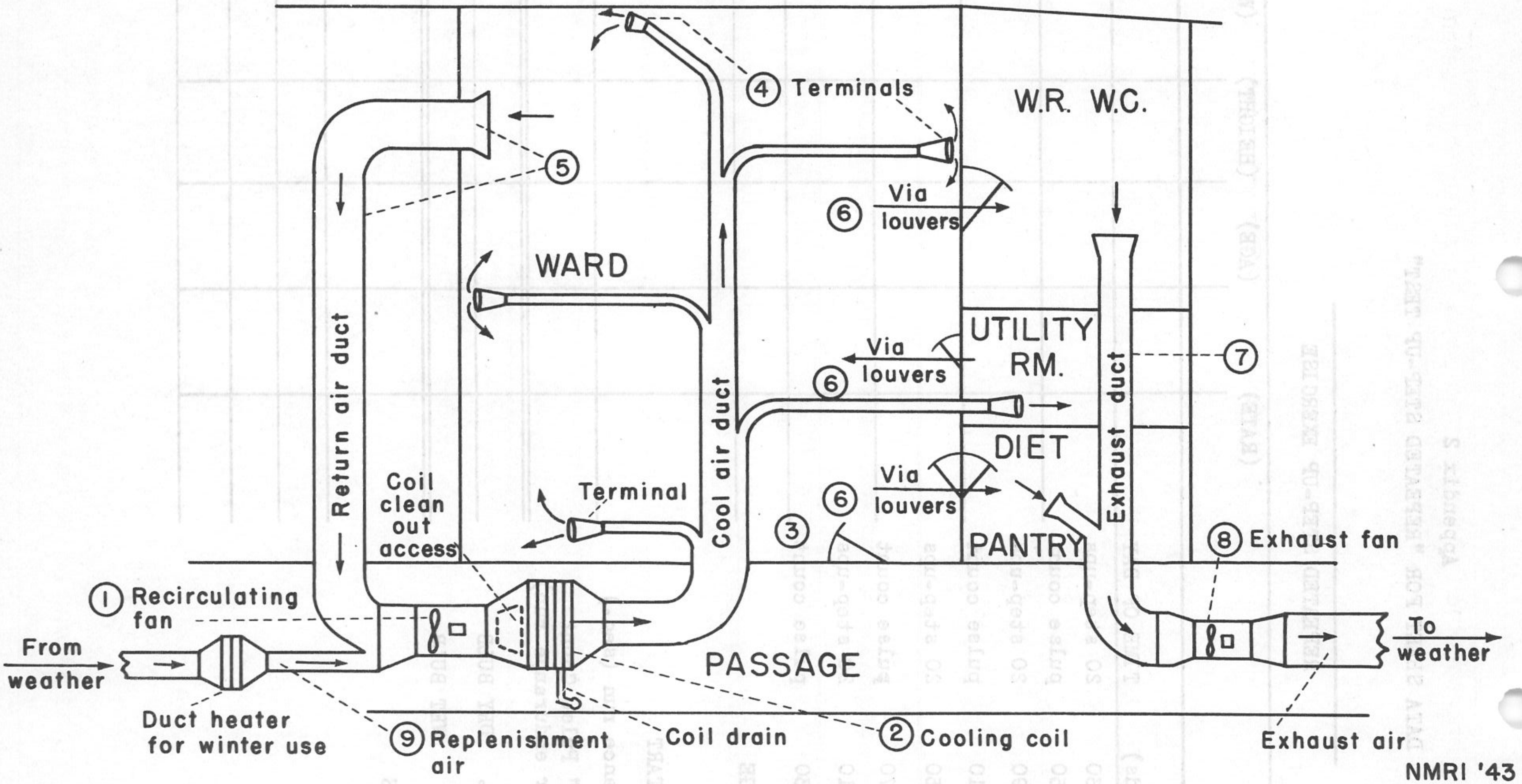
(NAME) (RATE) (AGE) (HEIGHT) (WEIGHT)

DATE

EXERCISE PERIODS	TIME (seconds)	TIME OF DAY						
1	0- 30	20 step-ups						
	35- 50	pulse count						
2	60- 90	20 step-ups						
	95-110	pulse count						
3	120-150	20 step-ups						
	155-170	pulse count						
4	180-210	20 step-ups						
	215-230	pulse count						
	AVERAGE							
ENDURANCE RUN								
	240 START							
	Endurance run (sec.)							
	5"-20" Pulse Count (after endurance run)							
COMPARTMENT TEMP.	DRY BULB							
	WET BULB							
BODY TEMPERATURES								
A.M.	Rectal							
	Oral							
P.M.	Rectal							
	Oral							

REMARKS:

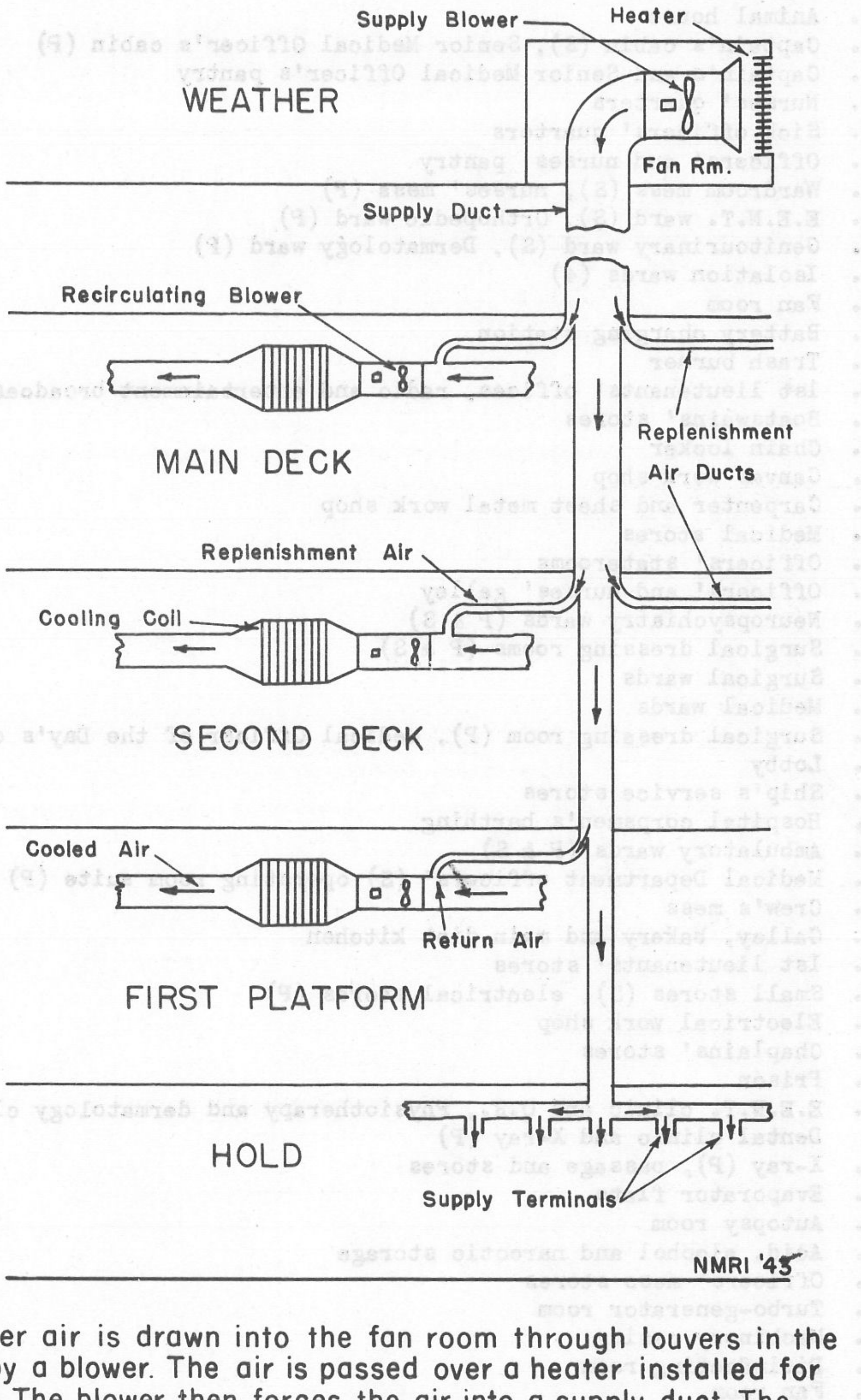
Typical cooling system for wards and companion spaces on "Haven" class hospital ships



Recirculating fan (1) forces air over coil (2) where it is cooled and dehumidified, then distributed by insulated duct (3) to the cooled spaces through terminals (4). Heat and moisture within the spaces served are picked up by the cool air and the resulting final conditions reached by this air represent the ambient temperature and humidity of the spaces. The resulting air is then drawn from the spaces through the return air duct (5), the louvers (6), and the exhaust system (7). The quantity of air which is removed by fan (8) is equal to that which will be added fresh from the weather. The fresh weather air, referred to as replenishment air (9), is added to the return air (5) before reentering fan (1) for the next cycle.

Appendix 4

Diagram illustrating a method of adding weather air to recirculating system

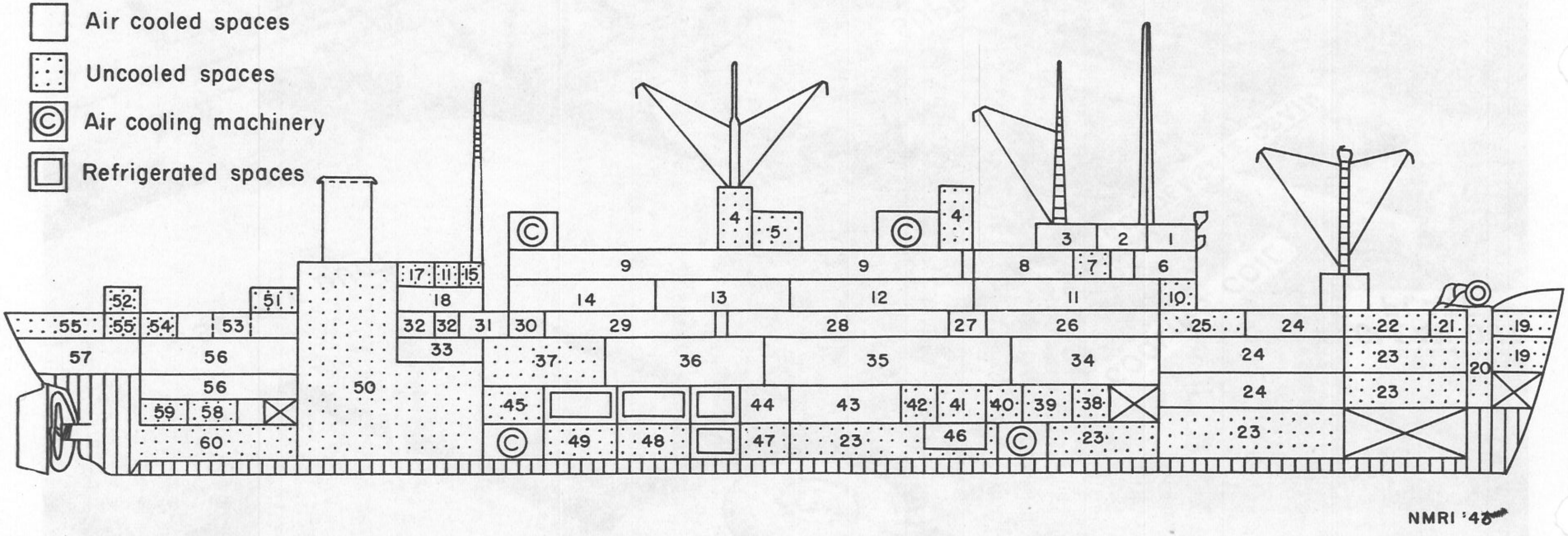


The weather air is drawn into the fan room through louvers in the bulkhead by a blower. The air is passed over a heater installed for winter use. The blower then forces the air into a supply duct. The weather air then enters each recirculating system where it is added to the recirculating air and passed over the cooling coil by the re-circulating fan. The remainder of the air passes down the supply duct to spaces which are not air cooled, such as storerooms.

Legend

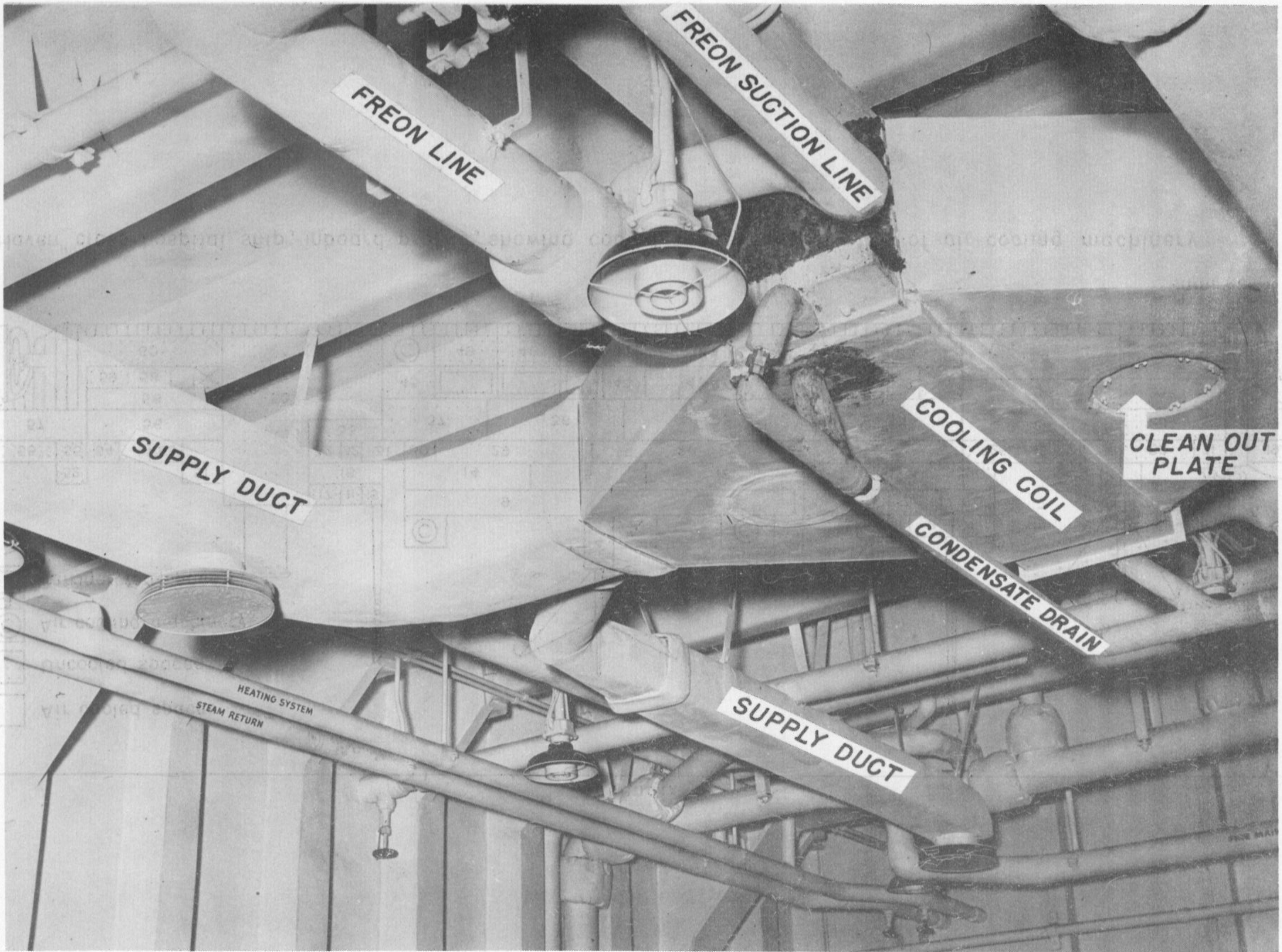
1. Pilot house
2. Chart house
3. Radio room and communications office
4. Elevator trunk
5. Animal house
6. Captain's cabin (S), Senior Medical Officer's cabin (P)
7. Captain's and Senior Medical Officer's pantry
8. Nurses' quarters
9. Sick officers' quarters
10. Officers' and nurses' pantry
11. Wardroom mess (S), nurses' mess (P)
12. E.E.N.T. ward (S), Orthopedic ward (P)
13. Genitourinary ward (S), Dermatology ward (P)
14. Isolation wards (4)
15. Fan room
16. Battery charging station
17. Trash burner
18. 1st lieutenants' offices, radio and entertainment broadcasting central
19. Boatswains' stores
20. Chain locker
21. Canvas work shop
22. Carpenter and sheet metal work shop
23. Medical stores
24. Officers' staterooms
25. Officers' and nurses' galley
26. Neuropsychiatry wards (P & S)
27. Surgical dressing rooms (P & S)
28. Surgical wards
29. Medical wards
30. Surgical dressing room (P), Medical Officer of the Day's office (S)
31. Lobby
32. Ship's service stores
33. Hospital corpsmen's berthing
34. Ambulatory wards (P & S)
35. Medical Department officers' (S) operating room suite (P)
36. Crew's mess
37. Galley, bakery and main diet kitchen
38. 1st lieutenants' stores
39. Small stores (S), electrical stores (P)
40. Electrical work shop
41. Chaplains' stores
42. Prison
43. E.E.N.T. clinic and O.R., Physiotherapy and dermatology clinic (S)
    Dental clinic and X-ray (P)
44. X-ray (P), passage and stores
45. Evaporator flats
46. Autopsy room
47. Acid, alcohol and narcotic storage
48. Officers' mess stores
49. Turbo-generator room
50. Machinery casing
51. Disinfecting room
52. Fan room
53. Officers' supply, disbursing, engineering ships
54. Linen room
55. Laundry
56. Crew's berthing
57. Steering engines
58. Inflammable liquids locker
59. Gasoline stowage
60. Shaft alley

Appendix 5



"Haven" class hospital ship, inboard profile, showing cooled spaces and location of air-cooling machinery

Appendix 6



NMRI '43

Typical cooling coil

Appendix 7

Section 638

AH14/S38(638c-5817-646)

Navy Department
Bureau of Ships
Washington 25, D. C.

25 Aug 1945

To: Commanding Officer, USS HAVEN (AH12)
c/o Fleet Post Office, San Francisco, Calif.

Commanding Officer, USS BENEVOLENCE (AH13)
c/o Fleet Post Office, San Francisco, Calif.

Commanding Officer, USS TRANQUILLITY (AH14)
c/o Fleet Post Office, San Francisco, Calif.

Commanding Officer, USS CONSOLATION (AH15)
c/o Fleet Post Office, San Francisco, Calif.

Commanding Officer, USS REPOSE (AH16)
c/o Fleet Post Office, San Francisco, Calif.

Commanding Officer, USS SANCTUARY (AH17)
c/o Fleet Post Office, New York, N. Y.

Subj: Hospital Ships AH12-17 - Air Conditioning Systems, Operating Instructions for.

Ref: (a) Survey of USS TRANQUILLITY (AH14) by BuShips and BuMed Personnel while ship was enroute to Panama, Canal Zone June 5-14, 1945.

1. As a result of reference (a), the following general instructions are given to assist the ship's force in properly operating and maintaining the air conditioning systems:

(a) RECIRCULATING FANS

(1) These fans should be continuously operated at all times as the load on each of the compressors is based on continuous operation of all fans on each system. When one or more fans of a system are shut down for long periods of time, the compressors for the system should be operated on slow speed to compensate for the reduction in load. If compressors are operated on high speeds under these conditions, the compressor will short cycle which may result in motor failures or high effective temperature within the remaining spaces.

(2) The actual air quantities for the recirculating systems are in excess of the designed air quantities and the attendant high velocities cause moisture carry-over from the coils. All systems should therefore be operated on slow speed at all times with the exception of the following:

01-54
02-104
02-106
02-147

Outside weather conditions permitting, all recirculating systems may be operated on high speeds providing the compressor plants are not operated.

(b) THERMOSTATS

(1) The thermostats should be set to maintain a dry bulb temperature of approximately 85° F. The resultant wet bulb temperature will depend upon the number of personnel in the compartment and other source of moisture present. The thermostat setting may be lowered if desired when the vessel operates for a prolonged period in moderate climates. The reduction in load, when operating under these conditions will probably require slow speed operation of all compressors to prevent short cycling. Resetting of thermostats should be avoided as much as possible.

(c) FREON COMPRESSORS (Air Conditioning)

(1) The compressors should be operated on their individual systems and on high or slow speed as necessary to maintain a suction pressure between 35 and 40 PSIG and a head pressure of approximately 125 PSIG. Operation of the compressors at suction pressures above 40 PSIG results in an evaporator temperature above that for which the coils were designed and will result in higher temperatures within the spaces cooled.

(2) Each set of compressors is cross connected as an emergency measure, however, when the plant load is light due to operation in moderate climates, one compressor can be operated on the two systems to prevent short cycling. The plant should not be operated in this manner, except in case of emergency, if the suction pressure exceeds 40 PSIG.

(3) Compressor plant No. 3 operating on the coils in crew's mess and Medical Ward C6 is fully loaded only when the mess hall is occupied at chow time or during movies. Best results will be obtained if this plant is operated on high speed about one hour before chow time and about one-half hour after chow time, otherwise the plant should be operated on slow speed. The plant should remain on high speed following the evening meal on evenings when the mess hall is to be used for movies.

(4) The compressor low pressure cut-out should be set to cut out between 20-25 PSIG and to cut in at from 60-70 PSIG. Compressor off cycles of 8 to 10 minute intervals should not be considered as excessive.

(d) EXPANSION VALVES

(1) The super heat setting of expansion valves can be checked by observing the suction line temperature at the stop valve in the suction line at the coil. Insert a screw driver between the insulation and the valve flange to make a hole for the thermometer. The thermometer should register a temperature of about $12^{o} - 15^{o}$ F. above the temperature corresponding to the suction pressure at the compressor. No additional allowance should be made for a pressure loss between the coil and the compressor which usually amounts to from $3^{o} - 5^{o}$ F.

(2) All expansion valves should be checked periodically for faulty operation to be certain that liquid freon does not flood back to the compressor.

(3) Hand expansion valves should be used only in cases of emergency and should not be left open for extended periods of time especially when a compressor cycles due to light loads. Hand expansion valves which remain open when the compressor cycles causes a liquid flood back on the compressor during the off cycle. Likewise, a hand expansion valve opened too wide on a system on which the compressor is operating continuously will cause liquid to flood back on the compressor. Liquid flooding back on a compressor may result in a machinery derangement.

(e) VENTILATION SYSTEMS (other than Recirculating)

(1) The operation of ventilation systems affects the performance of the air conditioning systems if improperly operated. If, for instance, the exhaust system in the galley is operated when the supply system is shut down, all of the cool air from the Crew's mess will be exhausted to the weather by the galley exhaust system and a load exceeding the design load will be put on the air conditioning plant. It is necessary that supply and exhaust fans serving spaces other than air conditioned spaces be operated simultaneously and similarly, i.e., both on high speed or both on low speed, at all times.

(2) An increased load is also placed on the compressors when hot air is drawn into the recirculating systems and it is necessary to keep all weather and hot engineering and commissary access doors closed at all times. It is recommended that the following be stenciled on both sides of all access doors to air conditioned spaces; "KEEP THIS DOOR CLOSED WHEN AIR CONDITIONING IS IN OPERATION".

(3) Frequently, ventilating systems operate improperly due to dirty coils, grease filters, screens, etc. A check-off list is probably the best method of preventing faulty operation of ventilation systems from dirt and grease accumulation. Grease filters and laundry tumbler drier screens should be cleaned daily and coils and insect or other screens should be cleaned as frequently as found necessary. Regular inspections should be made of these parts from a check-off list.

(f) GENERAL

There are many items which can be placed under this heading which will greatly assist in the proper operation of the air conditioning plants. A few of these are listed below;

(1) Frequently the number or size of light bulbs in a space are increased or existing high wattage lights are permitted to remain on when not in use. This practice will result in increased load on the air conditioning systems and will increase the temperatures in the space in which lights are so changed. Excessive illumination should be avoided.

(2) The removal of cleanout plates in duct systems to improve ventilation in a compartment should be discouraged as this

practice not only unbalances a system but results in high and uneven temperatures in various air conditioned spaces served by the system.

(3) Likewise, the removal of diffusing terminals will result in unbalancing a system and the practice should be discouraged.

(4) Moisture carry-over in many instances can be traced to fouled drain line. The fouling of drain lines is caused by dust and lint being deposited on the cooling coils and being carried to the drain pan by the condensate. The drain lines should be flushed or cleaned as frequently as necessary.

(5) Use of gauze or other material for filtering devices should be discouraged. If dirt is discharged from terminals it is apparent that the system needs cleaning.

(6) No attempt should be made to readjust air quantities as it is difficult to rebalance a system once it is unbalanced by readjusting air quantities.

(7) Curtains to staterooms should remain partially open as the access is a natural exhaust air opening for the staterooms.

(8) Freon joints should be checked frequently for leaks to prevent unnecessary plant shutdowns.

(9) Tampering with or adjusting controls by unauthorized personnel should be forbidden. Many instances of faulty operation can be traced to tampering.

(10) Hanging of clothes over terminals for drying should likewise be forbidden. Wet or damp clothes so dried create unnecessary odors and increased humidity in a compartment.

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